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Data Summary Report:
Nature and Extent of LA Contamination in the Forest

Libby Asbestos Superfund Site
Libby, Montana

August 2013

Contract No. EP-W-05-049
Work Assignment No. 329-RICO-08BC

Prepared for:

U.S. ENVIRONMENTAL PROTECTION AGENCY
Region 8

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Approvals:

Date: 8/22/13

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≥	greater than or equal to
%	percent
µm	micrometer
A	area of tree bark sample being analyzed
A_1	volume of suspension aliquot applied to filter in primary dilution
A_2	volume of suspension aliquot applied to filter in secondary dilution
ABS	activity based sampling
Ago	area of grid opening
C_{duff}	duff concentration
C_{water}	water concentration
CB&I	CB&I Federal Services, LLC
CDM Smith	CDM Federal Programs Corporation
CH	chrysotile
CHISQ	chi-square
CI	confidence interval
cm	centimeter
cm^2	square centimeters
cm^{-2}	per square centimeter
COC	chain of custody
D_c	diameter of the core
D_p	diameter of the pilot hole
DQA	data quality assessment
DQO	data quality objective
EDD	electronic data deliverable
EDS	energy dispersive spectroscopy
EFA	effective filter area
EPA	U.S. Environmental Protection Agency
ESAT	Environmental Sampling Assistance Team
F	fraction of the original sample applied to the filter
FSDS	field sample data sheet
g	gram
g^{-1}	per gram
GO	grid opening
ID	identification
ISO	International Standards Organization
L	liter
L^{-1}	per liter
L_{bark}	tree bark surface loading
LA	Libby amphibole
mL	milliliter
mm^2	square millimeters

M_a	mass of ash aliquot used in the suspension
M_t	total mass of ash
MFL	million fibers per liter of water
Ms/cm^2	million structures per square centimeter of tree bark
Ms/g	million structures per gram of duff
N	number of asbestos structures counted
N_c	number of cores
NAM	non-asbestos material
NFG	National Functional Guidelines
NPL	National Priorities List
NVLAP	National Voluntary Laboratory Accreditation Program
OA	other amphibole
OU3	Operable Unit 3
OU7	Operable Unit 7
QA	quality assurance
QAPP	quality assurance project plan
QA/QC	quality assurance/quality control
QATS	Quality Assurance Technical Support
QC	quality control
ROM	record of modification
S	analytical sensitivity
SAED	selective area electron diffraction
SAP	sampling and analysis plan
Shaw E&I	Shaw Environmental & Infrastructure Group
Site	Libby Asbestos Superfund Site
SOP	standard operating procedure
TAT	turn-around time
TEM	transmission electron microscopy
USFS	United States Forest Service
V	volume of water applied to filter
V_1	total suspension volume of primary dilution
V_2	total suspension volume of secondary dilution
V_a	volume of suspension applied to filter
V_t	total suspension volume

1 INTRODUCTION

1.1 Site Background

Libby is a community in northwestern Montana located 7 miles southwest of a vermiculite mine that operated from the 1920s until 1990. The mine began limited operations in the 1920s and was operated on a larger scale by the W.R. Grace Company from approximately 1963 to 1990. Studies revealed that the vermiculite from the mine contains amphibole-type asbestos, referred to as Libby amphibole (LA).

Epidemiological studies revealed that workers at the mine had an increased risk of developing asbestos-related lung disease (McDonald *et al.* 1986, 2004; Amandus and Wheeler 1987; Amandus *et al.* 1987; Whitehouse 2004; Sullivan 2007). Additionally, radiographic abnormalities were observed in 17.8 percent (%) of the general population of Libby including former workers, family members of workers, and individuals with no specific pathway of exposure (Peipins *et al.* 2003; Whitehouse *et al.* 2008; Antao *et al.* 2012; Larson *et al.* 2010, 2012a, 2012b). Although the mine has ceased operations, historic or continuing releases of LA from mine-related materials could be serving as a source of ongoing exposure and risk to current and future residents and workers in the area. The Libby Asbestos Superfund Site (Site) was listed on the U.S. Environmental Protection Agency (EPA) National Priorities List (NPL) in October 2002.

1.2 Document Purpose

Previous investigations conducted at the Site have demonstrated that LA is present in environmental source media (e.g., soil, tree bark, duff material) at locations in and around the mine. Sampling of soil, tree bark, and duff in the forested areas surrounding the mine occurred as part of the *Phase I Sampling and Analysis Plan for Operable Unit 3 (OU3)* (EPA 2007). Results of this sampling revealed that LA contamination extends well beyond areas that were historically actively mined (EPA 2013). Because LA contamination has been demonstrated to extend beyond areas where mining operations took place, the extent of LA contamination in the Libby Valley is unknown.

In 2012, EPA conducted a study, referred to as the *Nature and Extent of LA Contamination in the Forest*, to characterize the nature and extent of LA contamination in the forested areas surrounding the Site (EPA 2012a). This document summarizes the results of this study.

1.3 Document Organization

In addition to this introduction, this report is organized into the following sections:

Section 2 This section summarizes data management procedures, including sample collection, documentation, handling, custody, and data management.

Section 3 This section summarizes the design of the study, and describes the data that were collected in this study, the analytical methods used for estimating the level of LA in tree bark and duff, as well as the data reduction methods utilized in this report.

Section 4 This section summarizes the results for data that were collected as part of this study, including an evaluation of the levels of LA in tree bark and duff.

Section 5 This section presents the results of the data quality assessment, including a summary of program audits, modifications, data verification efforts, an evaluation of quality control samples, and a data adequacy assessment.

Section 6 This section provides full citations for all analytical methods, site-related documents, and scientific publications referenced in this document.

All referenced tables and figures are provided at the end of this document. All referenced appendices are provided electronically.

2 DATA MANAGEMENT

2.1 Sample Collection, Documentation, Handling, and Custody

All samples generated as part of this study were collected, documented, and handled in accordance with Libby-specific standard operating procedures (SOPs), as specified in the governing sampling and analysis plan/quality assurance project plan (SAP/QAPP) (EPA 2012a).

All samples collected in this study were identified with sample identification numbers (IDs) that include a program-specific prefix of “NE” (i.e., NE-00079 and higher). Data on the sample type, location, collection method, and collection date of all samples were recorded both in a field log book maintained by the field sampling team and on a field sample data sheet (FSDS) designed to facilitate data entry into the field Scribe project database (see Section 2.4). All samples collected in the field were maintained under chain of custody (COC) during sample handling, preparation, shipment, and analysis.

2.2 Analytical Results Recording

Standardized data entry spreadsheets (electronic data deliverables, or EDDs) have been developed specifically for the Libby project to ensure consistency between laboratories in the presentation and submittal of analytical data. In general, a unique EDD has been developed for each analytical method and each medium. Each EDD provides the analyst with a standardized laboratory bench sheet and accompanying data entry form for recording analytical data. The data entry forms contain a variety of built-in quality control functions that improve the accuracy of data entry and help maintain data integrity. These spreadsheets also perform automatic computations of analytical input parameters (e.g., sensitivity, dilution factors, and concentration), thus reducing the likelihood of analyst calculation errors. The EDDs generated by the laboratories are uploaded directly into the Libby site database (see Section 2.4).

2.3 Hard Copy Data Management

Hard copies of all FSDSs, field logbooks, and COCs generated during this study are stored in the CDM Smith field office in Libby, Montana. **Appendix A.1** of this report provides copies of the field documentation.

All analytical bench sheets are scanned and included in the analytical laboratory job reports. These analytical reports are submitted to the Libby laboratory coordinator (i.e., EPA’s Environmental Services Assistance Team [ESAT] contractor, TechLaw) and stored electronically. **Appendix A.2** of this report provides copies of all the analytical laboratory reports for analyses performed as part of this study.

2.4 Electronic Data Management

Detailed information regarding electronic data management procedures and requirements can be found in the *EPA Data Management Plan for the Libby Asbestos Superfund Site* (EPA 2012b). In brief, sample and analytical electronic data are stored and maintained in the Libby Scribe project databases which are housed on a local computer located at the TechLaw office in Golden, Colorado, which is backed up daily to an external hard drive.

Because data for the Libby project are maintained in multiple Scribe projects (e.g., analytical data are managed in annual projects, field information is managed in a project separate from the analytical information), the data have been combined into one Microsoft Access® database by CDM Smith reflecting a compilation of tables from multiple Scribe projects.

Raw data summarized in this report were downloaded from Scribe.NET on 8/13/2013. A frozen copy of this Access database is provided in **Appendix B** of this report. Any changes made to these Scribe projects since this download will not be reflected in the Access database.

3 NATURE AND EXTENT OF LA IN THE FOREST STUDY

3.1 Study Design

The purpose of the study was to collect data on LA contamination in tree bark and forest duff that can be used to evaluate the nature and extent of LA levels in the forested areas surrounding the Site. Detailed information on this sampling study, including study-specific data quality objectives (DQOs) are provided in the governing SAP/QAPP (EPA 2012a).

3.2 Sampling Locations

A total of 51 locations[1] were sampled from within a two-mile buffer extending beyond the NPL boundary located east of Kootenai Falls[2] (see **Figure 3-1**). Sampling locations were placed in areas accessible *via* United States Forest Service (USFS) roads with adequate tree cover. To the extent possible, the precise sampling locations were placed in open areas that were not likely to have been substantially shielded from airborne deposition of asbestos by local features.

3.3 Sample Collection

Tree bark and duff samples were collected from October 8 to 18, 2012. For each of the 51 locations, sampling began with the collection of one tree bark composite sample (composed of individual cores from three different trees). Following bark collection, one duff composite sample was collected, collecting duff materials near each of the three trees sampled for tree bark. The following subsections describe sample collection methods for tree bark and duff.

3.3.1 Tree Bark

Tree bark samples were collected in accordance with Site-specific SOP EPA-LIBBY-2012-12, *Sampling and Analysis of Tree Bark for Asbestos*, with modifications as specified in the governing SAP/QAPP (EPA 2012a). In brief, a hole saw and chisel were used to collect a circular bark sample from each of three trees, which was composited into a single sample for analysis of LA by transmission electron microscopy (TEM). **Figure 3-2** provides example photographs of the collection of tree bark samples. **Appendix C** provides photographs for the collection of tree bark from all locations.

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[1] One additional sampling location was added to the 50 locations originally specified in the SAP/QAPP (see Section 5.2 for details).

[2] It was anticipated that the area west of Kootenai Falls would be sampled as part of another sampling effort, conducted specifically to support Operable Unit 7 (OU7; Troy).

3.3.2 Duff

Samples of duff material were collected in accordance with Site-specific SOP EPA-LIBBY-2012-11, *Sampling and Analysis of Duff for Asbestos*, with modifications as specified in the governing SAP/QAPP (EPA 2012a). In brief, at each specified sampling location, any fresh or partially decayed organic debris (e.g., twigs, leaves, pine needles) was collected by hand from the soil surface, taking care to ensure that the top layer of soil beneath the organic debris was not included in the duff material sample. **Figure 3-3** provides example photographs of the collection of duff samples. **Appendix C** provides photographs for the collection of duff from all locations.

3.4 Sample Preparation and Analysis

This section discusses the sample preparation, analysis methods, and analytic stopping rules for tree bark and duff.

3.4.1 Tree Bark

3.4.1.1 Sample Preparation

Tree bark samples were prepared and analyzed in accordance with the procedures specified in SOP EPA-LIBBY-2012-12, *Sampling and Analysis of Tree Bark for Asbestos* with modifications as specified in the governing SAP/QAPP. In brief, at the analytical laboratory, each composite sample (consisting of three bark cores) was dried and ashed, and an aliquot[3] of the resulting ash residue was acidified, suspended in water, and filtered. The resulting filter was used to prepare a minimum of three grids using the grid preparation techniques described in Section 9.3 of International Standards Organization (ISO) Method 10312:1995(E) (ISO 1995). Any remaining ash material was archived for possible future analysis.

For 10% of the tree bark samples, two additional filter replicates were prepared (using additional aliquots of the ash residue) and analyzed to gain an understanding of the within-sample variability. These samples were selected *post hoc* by EPA (i.e., after the results had been received for the field samples) so that a range of LA levels in tree bark are represented.

3.4.1.2 Analysis Method and Counting Rules

Grids were examined by TEM in basic accordance with the recording procedures described in ISO 10312:1995(E), as modified by the most recent versions of Libby Laboratory Modifications LB-000016, LB-000029, LB-000066, LB-000067, and LB-000085. During the analysis, the analyst recorded the size (length, width) and mineral type of each individual asbestos structure that was observed. Only asbestos structures having a length greater than or equal to (≥) 0.5

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[3] See Section 5.2 for a description of a tree bark sample preparation deviation (as documented in Libby Laboratory Modification LB-000092); affected samples are denoted in the Section 4 tables.

micrometers (µm) and an aspect ratio (length:width) ≥ 3:1, were recorded as countable structures. Mineral type was determined by selected area electron diffraction (SAED) and energy dispersive spectroscopy (EDS), and each structure was assigned to one of the following four categories:

LA Libby-class amphibole. Structures having an amphibole SAED pattern and an elemental composition similar to the range of fiber types observed in ores from the Libby mine (Meeker *et al.* 2003). This is a solid solution series of minerals including winchite and richterite, with lower amounts of tremolite, magnesio-arfvedsonite, magnesio-riebeckite, and edenite/ferro-edenite. Depending on the valence state of iron, some minerals may also be classified as actinolite.

OA Other amphibole-type asbestos fibers. Structures having an amphibole SAED pattern and an elemental composition that is not similar to fiber types from the Libby mine. Examples include crocidolite, amosite, and anthophyllite. There is presently no evidence that these fibers are associated with the Libby mine.

CH Chrysotile fibers. Structures having a serpentine SAED pattern and an elemental composition characteristic of chrysotile. There is presently no evidence that these fibers are associated with the Libby mine. *For the purposes of this study, chrysotile structures were recorded if observed, but chrysotile structure counting stopped after 25 structures were recorded.*

NAM Non-asbestos material. These may include non-asbestos mineral fibers such as gypsum, glass, or clay, and may also include various types of organic and synthetic fibers derived from carpets, hair, etc. *Recording of NAM structures was not required.*

Meeker *et al.* (2003) also observed that most asbestos structures originating from the Libby vermiculite ore body contain detectable levels of both sodium and potassium, whereas other potential sources of LA may not. Thus, information on the sodium and potassium content and mineral classification (e.g., tremolite, winchite), as determined by EDS, of each amphibole asbestos structure observed was also recorded.

3.4.1.3 Stopping Rules

The stopping rules for the TEM analysis of tree bark were as follows:

1. Examine a minimum of two grid openings from each of two grids.
2. Continue examining grid openings until one of the following is achieved:
    a. The target analytical sensitivity (100,000 per square centimeter [cm^{-2}]) is achieved.
    b. 50 total LA structures have been observed.

c. A total filter area of 1.0 square millimeters (mm^2) has been examined (this is approximately 100 grid openings).

When one of these criteria was satisfied, the examination of the final grid opening was completed and counting stopped.

3.4.1.4 Results Reporting

The results for each tree bark analysis are expressed in terms of surficial loading (million structures per square centimeter [Ms/cm^2]) of tree bark. The surface loading of LA on tree bark is given by:

Surface loading on tree bark (L_{bark}) = N · S / 1E+06

where:

L_{bark} = Surface loading on tree bark (Ms/ cm^2)

N = Number of total LA structures observed

S = Analytical sensitivity (cm^{-2})

1E+06 = Conversion factor to report concentration in terms of million structures

The analytical sensitivity is calculated using the following equation:

$$S = \frac{EFA}{GO \cdot Ago \cdot A \cdot F}$$

where:

S = Sensitivity (cm^{-2})

EFA= Effective filter area (mm^2)

GO = Number of grid openings counted

Ago = Area of one grid opening (mm^2)

A = Area of tree bark sample being analyzed (cm^2), calculated as:

$$A = N_c \cdot [(\pi \cdot (D_c/2)^2) - (\pi \cdot (D_p/2)^2)]$$

where:

N_c = number of cores

π = pi (3.14159265…)

D_c = diameter of the core (centimeters [cm])

D_p = diameter of the pilot hole (cm)

F = Fraction of original sample deposited on the filter, calculated as:

$$F = M_a/M_t \cdot A_1/V_1 \cdot A_2/V_2$$

where:

M_a = mass of ash aliquot used in the suspension in grams (g)

M_t = total mass of ash (g)

A_1 = volume of suspension aliquot applied to filter in primary dilution (milliliters [mL])

V_1 = total suspension volume of primary dilution (mL)

A_2 = volume of suspension aliquot applied to filter in secondary dilution (mL)

V_2 = total suspension volume of secondary dilution (mL)

3.4.1.5 Combining Results from Multiple Replicate Filters

The best estimate of the mean tree bark surface loading across a set of multiple samples is calculated simply by averaging the individual surface loading values. Note that samples with a count of zero (and hence a surface loading of zero) are evaluated as zero when computing the best estimate of the mean (EPA 2008). This approach yields an unbiased estimate of the true mean that does not depend on the analytical sensitivity of the samples included in the data set.

3.4.2 Duff

3.4.2.1 Sample Preparation

Duff samples were prepared and analyzed in basic accordance with the procedures specified in SOP EPA-LIBBY-2012-11, *Sampling and Analysis of Duff for Asbestos*. In brief, at the analytical laboratory, each sample was dried, ashed, and an aliquot[4] of the resulting ash residue was acidified, suspended in water, and filtered. The resulting filter was used to prepare a minimum of three grids using the grid preparation techniques described in Section 9.3 of ISO 10312:1995(E). Any remaining ash material was archived for possible future analysis.

For 10% of the duff samples, two additional filter replicates were prepared (using additional aliquots of the ash residue) and analyzed to gain an understanding of the within-sample variability. These samples were selected *post hoc* by EPA so that a range of LA concentrations in duff are represented.

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[4] See Section 5.2 for a description of a duff sample preparation deviation (as documented in Libby Laboratory Modification LB-000092); affected samples are denoted in the Section 4 tables.

3.4.2.2 Analysis Method and Counting Rules

Grids were examined by TEM in the same manner as described for tree bark samples in Section 3.4.1.2.

3.4.2.3 Stopping Rules

The stopping rules for the TEM analysis of duff materials were as follows:

1. Examine a minimum of two grid openings from each of two grids.
2. Continue examining grid openings until one of the following is achieved:
   a. The target analytical sensitivity (1E+07 per gram [g^{-1}] dry weight) is achieved.
   b. 50 total LA structures have been observed.
   c. A total filter area of 1.0 mm^2 has been examined (this is approximately 100 grid openings).

When one of these criteria was satisfied, the examination of the final grid opening was completed and counting stopped.

3.4.2.4 Results Reporting

The result for each duff analysis was expressed in terms of million structures per gram of duff (Ms/g) (dry weight). The concentration of LA in duff is given by:

$$C_{duff} = N \cdot S \,/\, 1E{+}06$$

where:

C_{duff} = Duff concentration (Ms/g)

N = Number of total LA structures observed

S = Analytical sensitivity (g^{-1})

1E+06 = Conversion factor to report concentration in terms of million structures

For duff, the analytical sensitivity is calculated as:

$$S = EFA \,/\, (GOx \cdot Ago \cdot Mass \cdot F)$$

where:

S = Analytical sensitivity (g^{-1})

EFA = Effective filter area (mm^2)

GO = Number of grid openings counted

Ago = Area of a grid opening (mm^2)

Mass = Mass of the dried (but not ashed) duff sample (g)

F = Fraction of the dried duff sample applied to the filter, calculated as:

$$F = M_a/M_t \cdot V_a/V_t$$

where:

M_a = mass of ash aliquot used in the suspension (g)

M_t = total mass of ash (g)

V_a = volume of suspension aliquot applied to filter (mL)

V_t = total suspension volume (mL)

3.4.2.5 Combining Results from Multiple Replicate Filters

The best estimate of the mean duff concentration across a set of multiple samples is calculated simply by averaging the individual concentration values. Note that samples with a count of zero (and hence a concentration of zero) are evaluated as zero when computing the best estimate of the mean (EPA 2008). This approach yields an unbiased estimate of the true mean that does not depend on the analytical sensitivity of the samples included in the data set.

3.4.3 Equipment Rinsate Water

3.4.3.1 Sample Preparation

All equipment rinsate water samples were prepared for asbestos analysis in accordance with the techniques in EPA Method 100.2, as modified by Libby Laboratory Modification LB-000020A. In brief, all water samples were prepared using an ozone/ultraviolet treatment that oxidizes organic matter that is present in the water or on the walls of the bottle, destroying the material that causes clumping and binding of asbestos structures. Following treatment, an aliquot of water (generally about 50 mL) was filtered through a 25-millimeter diameter polycarbonate filter with a pore size of 0.1-µm with a mixed cellulose ester filter (0.45-µm pore size) used as a support filter. Approximately one quarter of the filter was used to prepare a minimum of three grids using the grid preparation techniques described in Section 9.3 of ISO 10312:1995(E).

3.4.3.2 Analysis Method and Counting Rules

Grids were examined by TEM in the same manner as described for tree bark samples in Section 3.4.1.2.

3.4.3.3 TEM Stopping Rules

The TEM stopping rules for equipment rinsate water samples were consistent with the analytical requirements specified in other water sampling efforts conducted at the Site. The stopping rules were as follows:

1. Examine a minimum of two grid openings from each of two grids.
2. Continue examining grid openings until one of the following is achieved:
   a. The target analytical sensitivity of 50,000 L^{-1} has been achieved.
   b. 25 total LA structures have been observed.
   c. A total filter area of 1.0 mm^2 has been examined (this is approximately 100 grid openings).

When one of these criteria was satisfied, examination of the final grid opening was completed and counting stopped.

3.4.3.4 Results Reporting

The result for each equipment rinsate analysis was expressed in terms of million fibers per liter of water (MFL). The concentration of LA in water is given by:

$$C_{water} = N \cdot S \ / \ 1E{+}06$$

where:

C_{water} = Water concentration (MFL)

N = Number of LA structures observed

S = Analytical sensitivity (L^{-1})

1E+06 = conversion factor to report concentration in terms of million fibers

For water, the analytical sensitivity is calculated as:

$$S = EFA \ / \ (GOx \cdot Ago \cdot V)$$

where:

S = Analytical sensitivity $(L)^{-1}$

EFA = Effective area of the filter (mm^2)

GOx = Number of grid openings examined

Ago = Area of a grid opening (mm^2)

V = Volume of water applied to the filter (liters [L])

4 RESULTS

Table 4-1 presents a tabular summary of the results for tree bark and duff. **Figure 4-1** presents a map of these tree bark and duff results. In this map, tree bark results are shown as a circle symbol and duff results are shown as a triangle symbol. Each symbol is color-coded based on the reported LA level.

4.1 Tree Bark

As seen in **Table 4-1** and **Figure 4-1**, LA was detected in 23 of 51 tree bark samples. Surface loading values of total LA for detected samples ranged from less than 0.01 to about 3 Ms/cm^2, with most detected samples (14 of 23 samples) having less than 0.1 Ms/cm^2. Only one sample had a surface loading value greater than 1 Ms/cm^2. LA was detected in tree bark as far as 13.8 miles from the mine, but there were no apparent spatial trends noted (i.e., locations in the downwind direction of the mine did not have concentrations that were different from locations in the upwind or crosswind direction).

Of the 245 LA structures observed in the tree bark analyses, 227 structures (93%) were characterized as containing sodium and potassium, which suggests that they originated from the Libby vermiculite ore deposit. As shown in **Figure 4-2**, no spatial pattern was noted in the sodium and potassium content of LA structures recorded as part of this study (i.e., the frequency of structures with sodium and potassium did not appear to decrease as a function of distance from the mine).

4.2 Duff

As seen in **Table 4-1** and **Figure 4-1**, LA was detected in 20 of 51 duff samples. Duff total LA concentrations ranged from 0.3 to 25 Ms/g, with most detected samples (16 of 20 samples) having less than 10 Ms/g. Four duff samples had LA concentrations greater than 10 Ms/g. LA was detected in duff as far as 16.9 miles from the mine. Similar to tree bark, there were no apparent spatial trends in the data; however, it is notable that three of the four duff samples with the highest concentrations of LA were in the downwind direction from the mine.

Of the 72 LA structures observed in the duff analyses, 58 structures (81%) were characterized as containing sodium and potassium, which suggests that they originated from the Libby vermiculite ore. No spatial pattern was noted in the sodium and potassium content of LA structures (see **Figure 4-2**).

4.3 Interpretation Relative to Other Datasets

As noted previously, extensive data on LA in tree bark and duff were collected in the forested area near the mine site as part of the Phase I investigation for OU3 (EPA 2013). In the Phase I study, 74 tree bark and duff samples were collected along seven transects extending 6-8 miles out from the mine site. **Figure 4-3** presents a graph of the total LA levels in tree bark (Panel A) and duff (Panel B) as a function of distance from the mine for this study compared to the OU3 Phase I investigation. As shown, tree bark surface loading values and duff concentrations tend to be highest in samples collected closest to the mine (within about 3-4 miles) with levels generally less than 1 Ms/cm^2 for tree bark and 100 Ms/g for duff at distances beyond about 4 miles. Tree bark and duff levels measured during this study were much lower than levels measured near the mine site, and were similar to or lower than levels measured beyond 4 miles from the mine site.

These results show that there is the potential for LA exposure from disturbances of tree bark and duff in the forested areas surrounding Libby. However, it is not possible, based on tree bark and duff measurements alone, to determine if inhalation exposures would be of potential concern. This is because the amount of LA that could be released to air is dependent upon several factors, including the level of LA in the source material, source moisture content, meteorological conditions, and type and intensity of the disturbance activity. A determination of potential exposures would require measurements of air within the breathing zone of the exposed individual during representative disturbance activities. This type of sampling is referred to as activity-based sampling (ABS). Thus, ABS data would be needed to determine if disturbances of tree bark and duff in the forested areas surrounding Libby could result in unacceptable LA exposure levels.

5 DATA QUALITY ASSESSMENT

Data quality assessment (DQA) is the process of reviewing existing data to establish the quality of the data and to determine how any data quality limitations may influence data interpretation (EPA 2006).

5.1 Oversight

5.1.1 Field

Field surveillances assess field processes and activities to verify adherence to investigation-specific requirements. Surveillances are similar to audits in this regard, but are intended to be more immediate in providing feedback to the surveyed party. The SAP/QAPP for this study originally identified that a field audit was to be performed; however, it was subsequently determined, based on consultation with the CDM Smith Quality Assurance (QA) manager, that a field surveillance would better meet the objectives of this study.

A field surveillance was conducted during the sampling event on October 9, 2012, by a qualified CDM Smith QA staff member (CDM Smith 2012). In brief, tree selection (size and species), tree bark and duff sampling, equipment decontamination, global positioning system point collection and field documentation (including logbooks, photographs, and FSDSs) were reviewed. The following deficiencies were identified:

1. Incorrect measurements of tree bark core diameter (circumferences were measured in the field but were recorded as measurements of diameter on the FSDS forms).
2. One section of an FSDS was crossed out but not initialed and dated.
3. Field documentation was not recorded on collection of tree bark samples from the “mine side” of the tree (i.e., the side of the tree facing the former vermiculite mine in Libby).

Corrective measures were immediately taken at the time of the surveillance to address the identified deficiencies.

5.1.2 Laboratory

Laboratory audits are conducted to evaluate laboratory personnel to ensure that samples are handled and analyzed in accordance with the program-specific documents and analytical method requirements (or approved Libby laboratory modification forms) to make certain that analytical results reported are correct and consistent. All aspects of sample handling, preparation, and analysis are evaluated. If any issues are identified, laboratory personnel are notified and retrained as appropriate.

A series of laboratory audits was performed in May-September of 2012 to evaluate all of the Libby laboratories. Detailed audit findings for each laboratory are documented in separate laboratory-specific audit reports (Shaw Environmental & Infrastructure Group [Shaw E&I] 2012a-g). No critical deficiencies were noted during the 2012 laboratory audits that would be expected to impact data quality for TEM analyses.

5.2 Field and Laboratory Modifications

All field deviations from, and modifications to, the governing SAP/QAPPs were recorded on a field Libby Record of Modification (ROM) form. The ROM forms are used to document all permanent and temporary changes to procedures contained in guidance documents governing the investigation that have the potential to impact data quality or usability. Any minor deviations (i.e., those that will not impact data quality or usability) have been documented in the field logbooks. **Appendix D** contains copies of all ROM forms associated with this study.

One field modification (LFO-000170) was created that documented changes from sample collection and analysis methodology specified in the SAP/QAPP (EPA 2012a). As noted in this field ROM, the following changes were made during field collection efforts:

- As requested by the USFS, an additional sampling location was added near the USFS Libby District's Canoe Gulch Ranger Station.
- Twenty-four sampling locations needed to be relocated due to inaccessibility from closed or decommissioned roads. The new locations were accessible and expected to be suitable substitutes for the original locations in terms of meeting the DQOs. All sampling locations shown in **Figure 4-1** are representative of the new locations.
- Collection of equipment rinsates was changed to one per team per day. The first rinsate collected was analyzed using high-priority turn-around time (TAT) to identify any potential cross-contamination/decontamination issues as quickly as possible.

None of these field modifications are expected to have a negative impact on data quality or usability.

One laboratory modification (LB-000092) was created that documented changes from the preparation methodology specified in the tree bark and duff collection and analysis SOPs. As documented this laboratory ROM, the following deviations occurred during the analysis of these samples:

- One of the TEM laboratories misinterpreted the preparation procedures and only analyzed one of the three collected bark cores. In addition, when performing the two bark replicate analyses, the laboratory analyzed each of the two remaining cores, rather than two additional aliquots of the original ash residue.
- This same TEM laboratory also misinterpreted the preparation procedures and split the unashed duff sample into several aliquots and only analyzed one aliquot. In addition, when performing the two duff replicate analyses, the laboratory analyzed two of the

archived unashed duff aliquots, rather than two additional aliquots of the original ash residue.

The tree bark and duff samples affected by this laboratory modification are denoted in the Section 4 tables. These deviations are not expected to have a negative impact on data quality; however, as a consequence of this deviation, the reported results for Replicate #1 for these samples are best interpreted as a grab sample and not a composite sample. Additionally, the subsequent replicate analyses performed by this laboratory (see Section 5.4.1.3) are not true replicate analyses, but are more similar to field duplicates. Consequently, the variability in LA levels between replicate analyses for these samples may higher.

5.3 Data Verification and Validation

The Libby Scribe project databases have a number of built-in quality control checks to identify unexpected or unallowable data values during upload into the database. Any issues identified by these automatic upload checks were resolved by consultation with the field teams and/or analytical laboratory before entry of the data into the database. After entry of the data into the database, several additional data verification steps were taken to ensure the data were recorded and entered correctly.

5.3.1 Data Verification

In order to ensure that the database accurately reflects the original hard copy documentation, all data downloaded from the database were examined to identify data omissions, unexpected values, or apparent inconsistencies. In addition, 10% of all samples and analytical results underwent a detailed verification. Asbestos data verification involves comparing the data for a sample in the database to information on the original hard copy FSDS form or the original hard copy analytical bench sheets for that sample.

Appendix E presents a detailed summary of the findings of the data verification efforts for this investigation. In brief, a total of 19 TEM analyses (8 tree bark analyses, 11 duff analyses) were reviewed in accordance with SOP EPA-LIBBY-09 as part of the data verification effort. There were no critical[5] issues identified during the TEM verification effort. Several non-critical discrepancies were identified during the TEM verification, in which data were either incorrectly recorded on the benchsheet or incorrectly transferred from the benchsheet to the EDD. Affected data fields included the laboratory name, laboratory sample number, and target sensitivity.

Hard copy FSDS forms for all samples selected for TEM verification (8 tree bark samples, 11 duff samples) were reviewed in accordance with SOP EPA-LIBBY-11. No critical issues were identified during the FSDS verification effort.

[5] A critical discrepancy is defined as an issue that could influence the reported sample concentration or sample identification information.

All issues identified during the data verification effort were submitted to the field teams and/or analytical laboratories for resolution and rectification. All tables, figures, and appendices (including all hard copy documentation and the database [provided in **Appendix A.1** and **Appendix A.2**, respectively]) generated for this report reflect corrected data.

5.3.2 Data Validation

Unlike data verification, where the goal is to identify and correct data reporting errors, the goal of data validation is to evaluate overall data quality and to assign data qualifiers, as appropriate, to alert data users to any potential data quality issues.

Data validation is performed by the EPA Quality Assurance Technical Support (QATS) contractor (CB&I Federal Services, LLC [CB&I]), with support from technical support staff that are familiar with investigation-specific data reporting, analytical methods, and investigation requirements. For the Libby project, data validation of TEM results is performed in basic accordance with Libby-specific SOPs that have been developed based on the draft *National Functional Guidelines (NFG) for Asbestos Data Review* (EPA 2011).

The EPA QATS contractor prepares an annual summary of the program-wide assessment of quality assurance and quality control (QA/QC). This annual addendum provides detailed information on the validation procedures performed and provides a narrative on the quality assessment for each type of analysis (e.g., TEM), including the data qualifiers assigned and the reason(s) for these qualifiers to denote when results do not meet acceptance criteria. This annual summary details any deficiencies, required corrective actions, and makes recommendations for changes to the QA/QC program to address any data quality issues.

A copy of the program-wide *2010-2012 QA/QC Summary Report* (CB&I 2013) pertaining to the data collected as part of this study is currently pending. When this report is finalized, it will be located on the Libby Lab eRoom. Interpretation of the data quality for this study is subject to change upon completion of this summary report.

5.4 Quality Control Sample Evaluation

5.4.1 Field Quality Control

Field-based quality control (QC) samples are those samples that are prepared in the field and submitted to the laboratory for analysis concomitant with the field samples. Two types of field QC were collected as part of this study – field duplicates and equipment rinsate blanks. Field duplicates were collected for both tree bark and duff. Equipment rinsate blanks were collected for tree bark.

In addition to these field QC samples, for 10% of the tree bark and duff samples, two additional filter replicates were prepared (using additional aliquots of the ash residue) and analyzed to gain an understanding of the within-sample variability. These samples were selected *post hoc* by EPA so that a range of LA levels were represented.

5.4.1.1 Field Duplicates

Field duplicates for tree bark and duff are a second sample using the same collection technique as the parent field samples. Three field duplicates were submitted for tree bark and three were duplicates were submitted for duff. The number of duplicate samples met the frequency requirements of 5% for both types of environmental media as specified in the SAP/QAPP (EPA 2012a). Field duplicates were blind to the analytical laboratories (i.e., the laboratory could not distinguish between field samples and field duplicates). Field duplicates were sent for analysis by the same method as the field samples.

For tree bark and duff, the original and field duplicate sample results were compared using the Poisson ratio test recommended by Nelson (1982). As shown in **Table 5-1**, with the exception of one duff sample, results were not statistically different based on a Poisson ratio test comparison (90% confidence interval). For duff, the results of one field sample were higher than the paired field duplicate, meaning that the difference between the reported concentration values is more than would be expected based on analytic variability (i.e., Poisson counting error) alone. These results show that there may be a high level of expected variability in duff results due to inherent media heterogeneity.

5.4.1.2 Equipment Rinsates

Equipment rinsate samples are collected to evaluate potential contamination that arises to due inadequate decontamination of the sampling equipment utilized during tree bark collection (i.e., hole saw, chisel). Following decontamination efforts of the field sampling equipment used to collect tree bark, the decontaminated equipment was be rinsed with distilled water and the resulting rinsate collected for analysis by TEM. A total of eight equipment rinsate samples were collected. The first equipment rinsate was analyzed using a high-priority TAT, to ensure that any potential decontamination issues could be identified quickly and resolved. No asbestos structures were observed in this analysis. Other equipment rinsates were archived pending the completion of the analysis of the tree bark samples.

Because nearly half of all tree bark samples collected as part of this study detected one or more LA structure, the remaining seven equipment rinsates were subsequently taken from archive and analyzed by TEM. No asbestos structures were observed in any of the equipment rinsate analyses. The results demonstrate that asbestos was not introduced into the bark samples as a consequence of sample collection, decontamination, shipping and handling, or analysis.

5.4.1.3 Filter Replicates

As noted above, 5 tree bark samples and 5 duff samples (10% for each media) were selected *post hoc* for the analysis of two additional filter replicates to provide information on the within-sample variability. **Table 5-2** presents the results for the 10 samples selected for replicate analysis. In this table, results for tree bark replicates are shown in Panel A and results for duff are shown in Panel B. Each replicate result was compared, on a pair-wise basis, using the Poisson ratio test recommended by Nelson (1982) based on a 90% confidence interval (CI).

As shown in **Table 5-2**, with three exceptions, sample results were not statistically different (based on a 90% Poisson CI) across replicate analyses. For sample NE-000087, the tree bark surface loading for total LA in Replicate #3 was lower than Replicate #2. For sample NE-00219, the tree bark surface loading for total LA in Replicate #2 was lower than both Replicate #1 and Replicate #3. For sample NE-00228, the duff concentration for total LA in Replicate #1 was higher than both Replicate #2 and Replicate #3. These results demonstrate the variability in the analysis results, even within an individual sample.

As discussed in Section 5.2, for those tree bark and duff samples affected Libby laboratory modification LB-000092 (noted in **Table 5-2**), the replicate analyses performed are not true replicate analyses, but are more similar to field duplicates. Thus, it is not unexpected that between-replicate results would be more variable for the affected samples. Two of the three replicates that were found to be statistically different (NE-00219 and NE-00228) were affected by this preparation modification.

5.4.2 Laboratory Quality Control

The Libby-specific QC requirements for TEM analyses of asbestos are patterned after the requirements set forth by the National Voluntary Laboratory Accreditation Program (NVLAP). In brief, there are three types of laboratory-based QC analyses for TEM – laboratory blanks, recounts, and repreparations. Detailed information on the Libby-specific requirements for each type of TEM QC analysis, including the minimum frequency rates, selection procedures, acceptance criteria, and corrective actions are provided in the most recent version of Libby Laboratory Modification LB-000029.

Laboratory QC analyses will evaluated by the EPA QATS contractor on a program-wide basis rather than on an investigation-specific basis. The rationale for this is that the number of preparation and laboratory QC samples directly related to this study is too limited to draw meaningful conclusions regarding overall data quality. Refer to the pending program-wide *2010-2012 QA/QC Summary Report* (CB&I 2013) for information regarding program-wide data quality of the analytical laboratories. As noted previously, interpretation of the data quality for this study is subject to change upon completion of this summary report.

5.5 Data Adequacy Evaluation

A comparison of the data collected as part of this study with the DQOs summarized in the governing SAP/QAPP (EPA 2012a) is presented below.

5.5.1 Completeness

The completeness of the dataset is described as a ratio of the amount of data expected from the field program versus the amount of valid data received from the laboratory. Valid data are considered to be those that have not been rejected during the validation process and have been verified at the specified frequency in the SAP/QAPP (EPA 2012a). Completeness can be expressed by the following equation:

$$\text{Completeness} = \frac{\text{(total number of valid results)}}{\text{(total number of requested results)}} \times 100$$

As shown in **Table 4-1**, all collected tree bark and duff samples were successfully prepared and analyzed by TEM in accordance with the methods and recording rules specified in the SAP/QAPP (EPA 2012a). Based on the data verification and data validation presented in Section 5.3.1 and Section 5.3.2, respectively, the completeness of the sample set is 100% for both tree bark and duff.

5.5.2 Analytical Requirements

5.5.2.1 Tree Bark

The stopping rules for the TEM analysis of tree bark were specified above in Section 3.4.1.2. Inspection of the detailed analytical results for tree bark (see **Appendix A.2**) shows that all analyses evaluated at least two grid openings from each of two grids. As shown in **Table 4-1**, all of the tree bark analyses met the target sensitivity of 100,000 cm^{-2}, with most analyses achieving sensitivities even lower than the target. Thus, all tree bark analyses achieved the analytical requirements specified in the SAP/QAPP (EPA 2012a).

5.5.2.2 Duff

The stopping rules for the TEM analysis of duff were specified above in Section 3.4.2.2. Inspection of the detailed analytical results for duff (see **Appendix A.2**) shows that all analyses evaluated at least two grid openings from each of two grids. As shown in **Table 4-1**, all of the duff analyses met the target sensitivity of 1E+07 g^{-1}, with most analyses achieving sensitivities even lower than the target. Thus, all duff analyses achieved the analytical requirements specified in the SAP/QAPP (EPA 2012a).

5.5.2.3 Equipment Rinsates

The stopping rules for the TEM analysis of equipment rinsates were specified above in Section 3.4.3.2. Inspection of the detailed analytical results for equipment rinsates (see **Appendix A.2**) shows that all analyses evaluated at least two grid openings from each of two grids and met the target sensitivity of 50,000 L^{-1}, with most analyses achieving sensitivities even lower than the target. Thus, all equipment rinsate analyses achieved the analytical requirements specified in the SAP/QAPP (EPA 2012a).

5.5.3 Evenness of Filter Loading

The TEM analysis of filters generated from tree bark and duff samples examines only a portion of the total filter. For the purposes of computing the tree bark surface loading or duff concentration in the sample, it is assumed that the filter is evenly loaded. The assessment of filter loading evenness is evaluated using a Chi-square (CHISQ) test, as described in ISO 10312 Annex F2. If a filter fails the CHISQ test for evenness, the reported result may not be representative of the true concentration in the sample, and the results should be given low confidence. Inspection of the p values for the tree bark and duff analyses shows that all filters passed the CHISQ test for evenness (i.e., p value > 0.001). Thus, it is concluded that uneven filter loading is not of significant concern for the samples analyzed in this study.

5.5.4 Data Adequacy Conclusions

Based on the data adequacy assessment presented above it is concluded that the data generated during this study meet the DQOs stated in the governing SAP/QAPP and results are adequate to support the data evaluations presented in this report.

5.6 Data Quality Conclusions

Taken together, these results indicate that data collected as part of this study are representative, of acceptable quality, and considered to be reliable and appropriate for use.

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FIGURES

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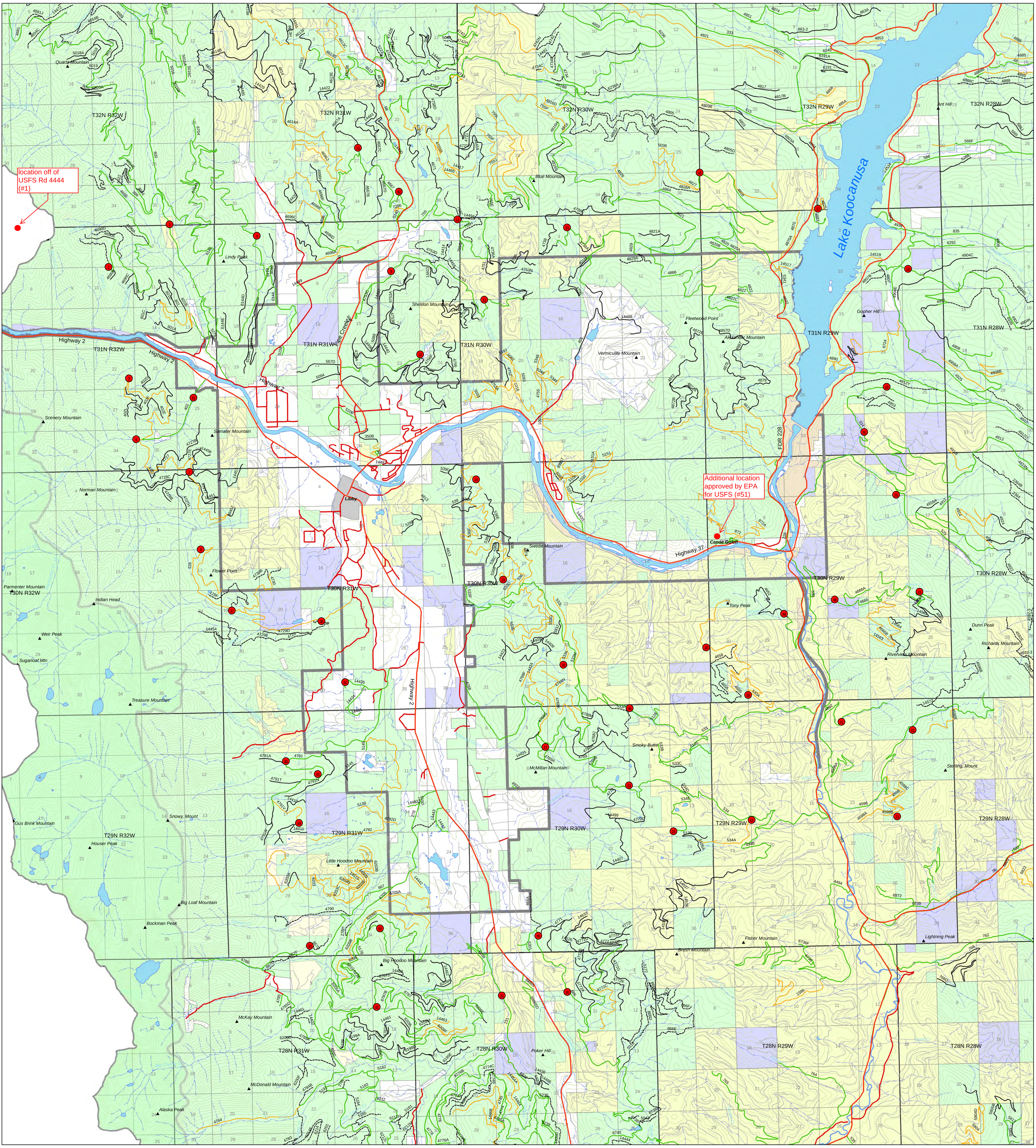


Figure 3 - 1

Tree Bark Duff Sample Locations

Legend

- TreeBark_Duff_SampleLocations
- Libby Ranger District Boundary
- Major Highways
- County Roads

NFSR Roads & Restrictions

- Open Yearlong
- Seasonal Restriction
- Restricted Yearlong to Motor and Snow Veh
- Restricted Yearlong to Motor, Open Snow Veh 12/01-04/30
- Other Roads
- Lakes & Rivers
- SIT_NPL_BNDS
- Wilderness

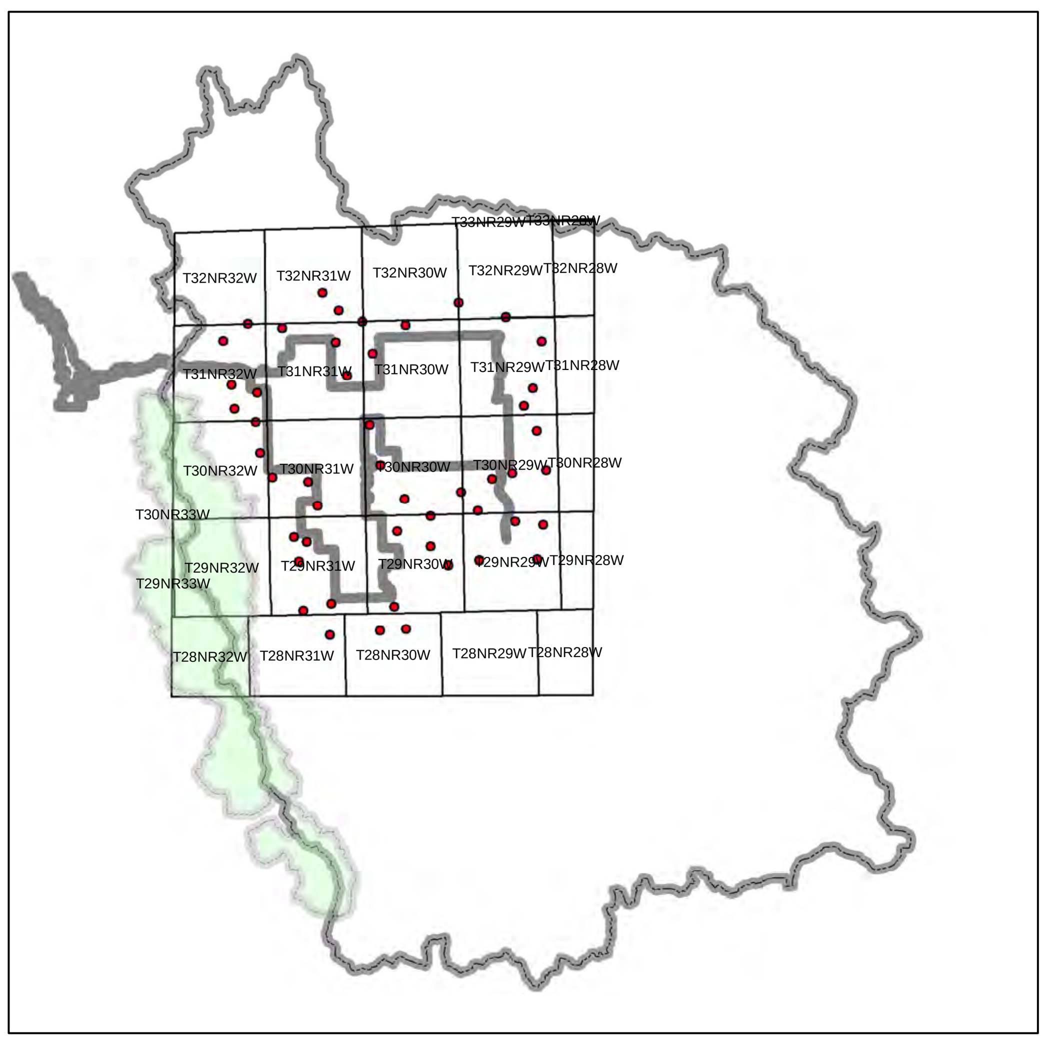
Ownership

- BLM
- Corp of Eng
- FS
- MT_State
- Other_Private
- Plum_Creek
- Stimson_Lumber
- USFWP

N S E W

0 0.5 1 2 3 4 Miles

1:63,360

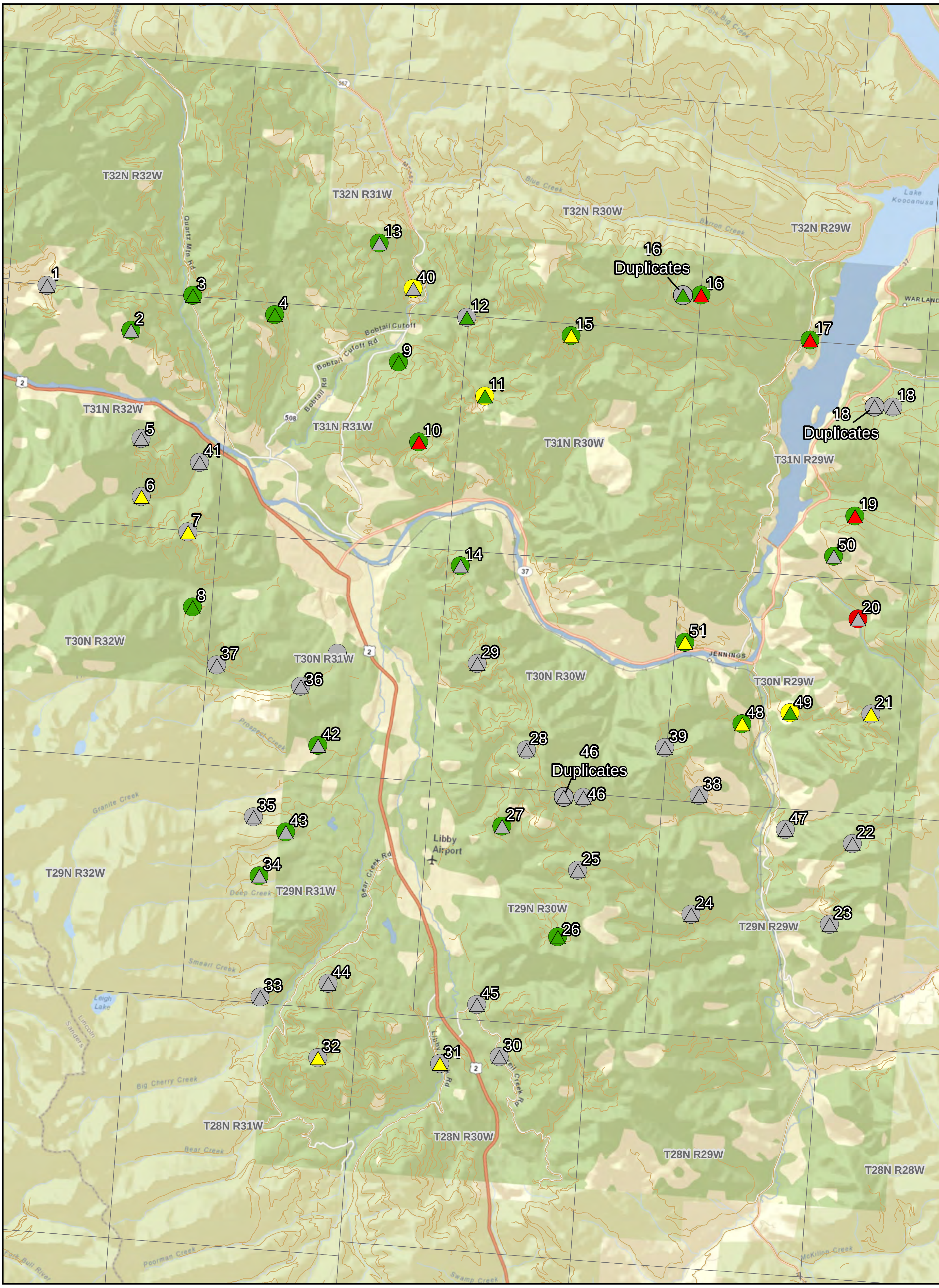


Data Sources:
NPL Boundary - U.S. EPA Region 8 (2011);
Timber Sales and Precommercial Tree Thinning - MT DNRC (2011)
Base - USFS (2012)

Figure 3-2

Example Photographs of Collection of Tree Bark Samples

Figure 3-3
Example Photographs of Collection of Duff Samples



Duff Results
Concentration

- Non-detect (0 Ms/g)
- >0 to 5 Ms/g
- >5 to 10 Ms/g
- >10 Ms/g

Tree Bark Results
Surface Loading

- Non-detect (0 Ms/cm^2)
- >0 to 0.5 Ms/cm^2
- >0.5 to 1 Ms/cm^2
- >1 Ms/cm^2
- Township and Range
- Forest Service Roads

Data Sources:
NPL Boundary - U.S. EPA Region 8 (2011);
Basemap - ESRI World Street Map Service

CDM Smith

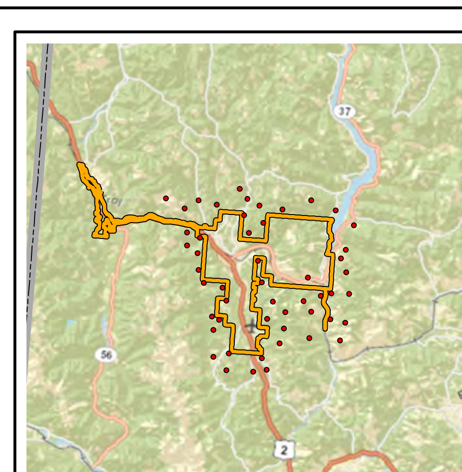
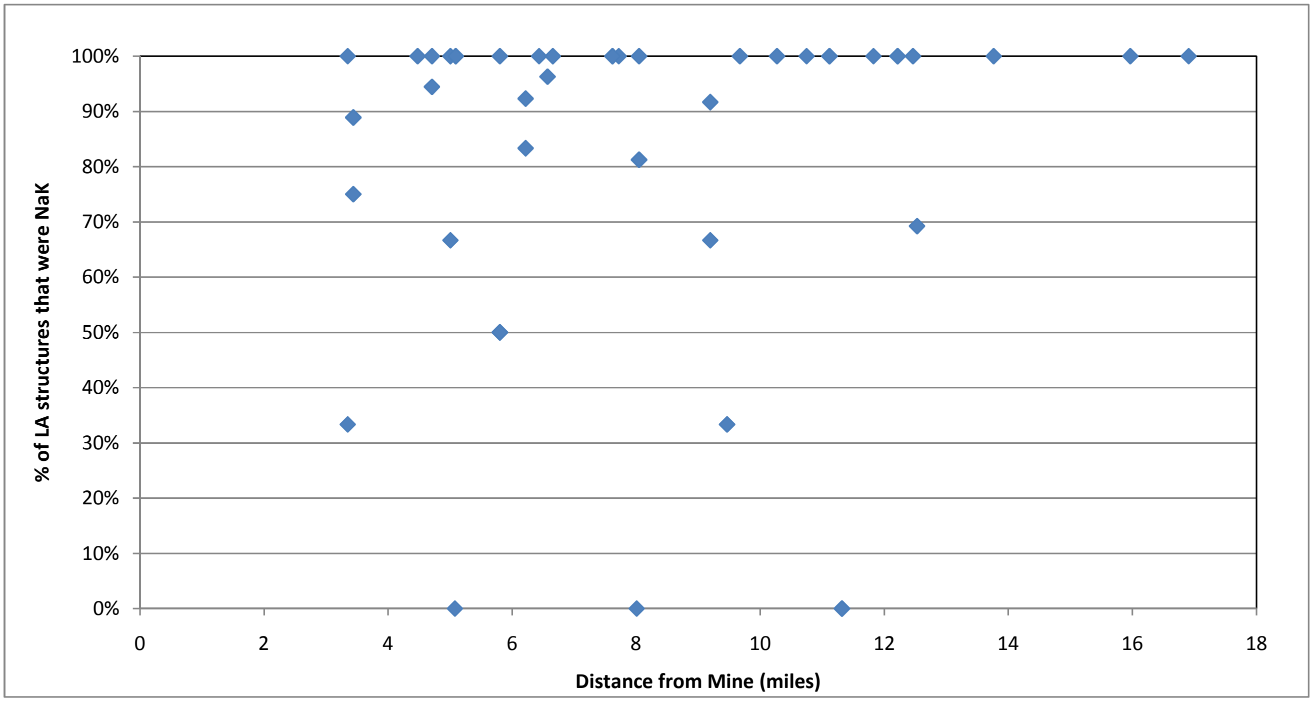


Figure 4-1
LA in Tree Bark and Forest Duff

N W E S

0 1.25 2.5 5
Miles
1 inch = 2.5 miles

FIGURE 4-2
SPATIAL PATTERN OF SODIUM AND POTASSIUM CONTENT OF LA STRUCTURES OBSERVED IN TREE BARK AND DUFF

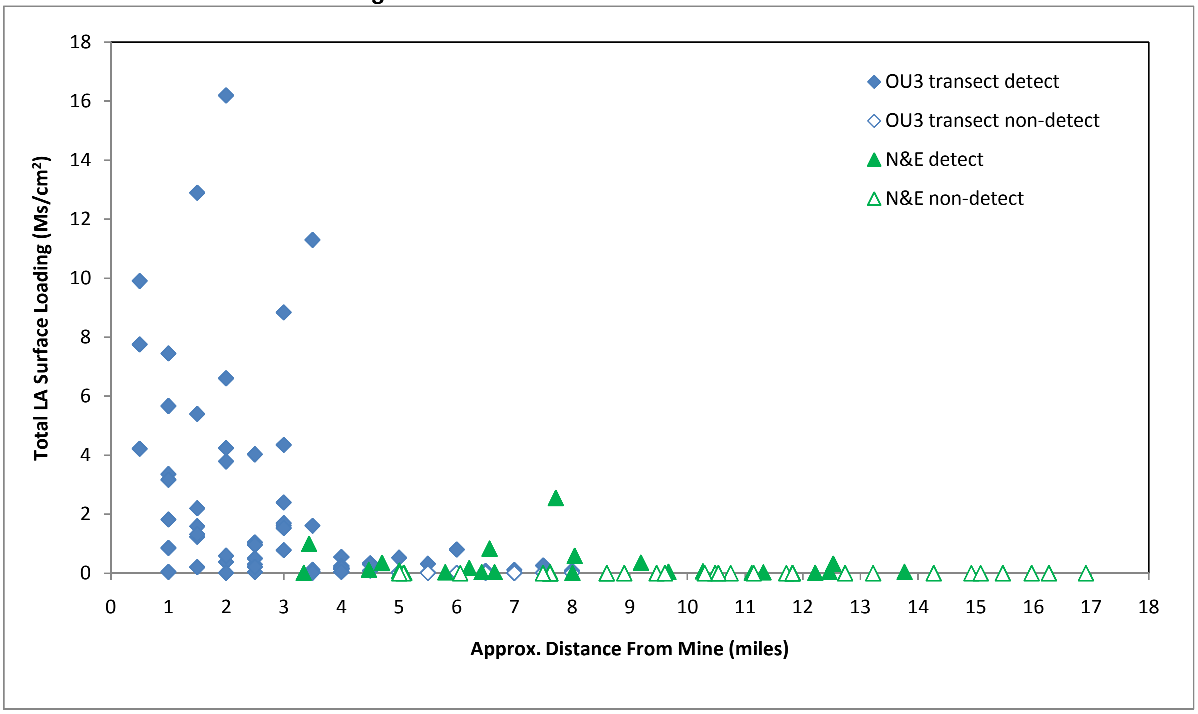


NaK = EDS for the structure included both sodium and potassium

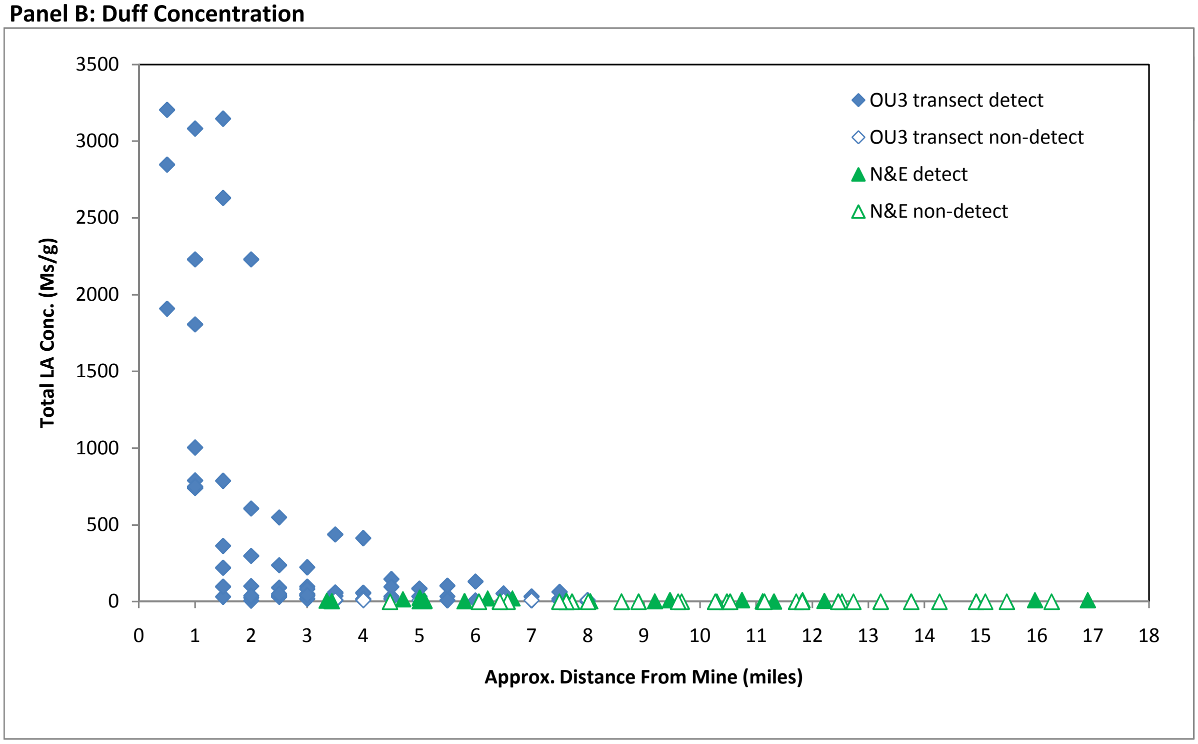
LA = Libby amphibole

Figure 4-3
Tree Bark and Duff Levels of LA as a Function of Distance from the Mine

Panel A: Tree Bark Surficial Loading



Panel B: Duff Concentration



LA = Libby amphibole
MS/cm^2 = million structures per square centimeter of tree bark
Ms/g = million structures per gram of duff
N&E = Nature & Extent Forest Study
OU3 = Operable Unit 3 Phase I Study

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TABLES

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TABLE 4-1
NATURE AND EXTENT OF LA IN TREE BARK AND DUFF FROM THE FOREST

Location	Approx. Distance from Mine Site (miles)	Tree Bark						Duff					
		Sample ID	Sensitivity (cm^{-2})	N Total LA Structures	Surface Loading (Ms/cm^2)		Poisson 90% CI on Surface Loading (Ms/cm^2)	Sample ID	Sensitivity (g^{-1})	N Total LA Structures	Conc. (Ms/g, dw)		Poisson 90% CI on Conc. (Ms/g)
Location #01	14.9	NE-00139	6.3E+04	0	0.00		0.00 - 0.12	NE-00140	8.8E+06	0	0.0		0.0 - 16.9
Location #02	12.5	NE-00209	2.4E+04	13	0.3	*	0.20 - 0.49	NE-00210	3.5E+05	0	0.0	*	0.0 - 0.7
Location #03	11.3	NE-00211	1.3E+04	2	0.03	*	0.01 - 0.07	NE-00212	3.2E+05	1	0.3	*	0.1 - 1.3
Location #04	9.2	NE-00213	2.9E+04	12	0.4	*+	0.21 - 0.55	NE-00214	4.7E+05	3	1.4	*	0.5 - 3.3
Location #05	11.8	NE-00141	6.3E+04	0	0.00		0.00 - 0.12	NE-00142	1.0E+07	0	0.0		0.0 - 19.2
Location #06	11.8	NE-00143	9.3E+04	0	0.00		0.00 - 0.18	NE-00144	9.9E+06	1	9.9		1.7 - 38.8
Location #07	10.7	NE-00145	9.3E+04	0	0.00		0.00 - 0.18	NE-00146	9.6E+06	1	9.6		1.7 - 37.6
Location #08	11.1	NE-00201	6.7E+03	1	0.007	*+	0.00 - 0.03	NE-00202	1.2E+06	1	1.2	*	0.2 - 4.9
Location #09	5.8	NE-00223	1.5E+04	2	0.03	*	0.01 - 0.08	NE-00224	2.1E+06	1	2.1	*	0.4 - 8.1
Location #10	4.7	NE-00225	8.6E+04	4	0.3	*	0.14 - 0.73	NE-00226	8.4E+05	18	15.1	*	10.1 - 21.9
Location #11	3.4	NE-00221	3.7E+04	27	1.0	*	0.72 - 1.35	NE-00222	5.8E+05	4	2.3	*	1.0 - 4.9
Location #12	5.1	NE-00215	1.3E+04	0	0.00	*	0.00 - 0.03	NE-00216	4.8E+05	6	2.9	*	1.4 - 5.4
Location #13	8.0	NE-00217	6.7E+03	1	0.007	*	0.00 - 0.03	NE-00218	1.2E+06	0	0.0	*	0.0 - 2.4
Location #14	4.5	NE-00115	2.8E+04	4	0.1		0.05 - 0.24	NE-00116	7.1E+06	0	0.0		0.0 - 13.6
Location #15	3.3	NE-00229	4.5E+03	3	0.01	*	0.00 - 0.03	NE-00230	2.8E+06	2	5.7	*+	1.6 - 15.7
Location #16	5.0	NE-00227	1.3E+04	6	0.08	*	0.04 - 0.15	NE-00228	3.6E+06	7	25.4	*	13.2 - 45.3
Location #16	*5.0*	*NE-00242*	*6.1E+04*	*0*	*0.00*	*	*0.00 - 0.12*	*NE-00243*	*4.6E+05*	*3*	*1.4*	*	*0.5 - 3.2*
Location #17	6.2	NE-00231	1.3E+04	13	0.2	*	0.11 - 0.27	NE-00232	3.4E+06	6	20.4	*	10.0 - 38.0
Location #18	7.6	NE-00079	2.6E+04	0	0.00		0.00 - 0.05	NE-00080	4.0E+05	0	0.0		0.0 - 0.8
Location #18	*7.6*	*NE-00081*	*1.1E+04*	*0*	*0.00*		*0.00 - 0.02*	*NE-00082*	*4.9E+05*	*0*	*0.0*		*0.0 - 0.9*
Location #19	6.7	NE-00207	3.6E+04	1	0.04		0.01 - 0.14	NE-00208	5.1E+06	4	20.4		8.5 - 43.1
Location #20	7.7	NE-00087	2.3E+04	110	2.6		2.18 - 2.98	NE-00088	5.7E+05	0	0.0		0.0 - 1.1
Location #21	9.5	NE-00233	1.5E+04	0	0.00	*+	0.00 - 0.03	NE-00234	2.9E+06	3	8.8	*	3.2 - 20.7
Location #22	11.7	NE-00093	4.1E+04	0	0.00		0.00 - 0.08	NE-00094	7.8E+05	0	0.0		0.0 - 1.5
Location #23	13.2	NE-00091	2.8E+04	0	0.00		0.00 - 0.05	NE-00092	1.1E+06	0	0.0		0.0 - 2.1
Location #24	11.8	NE-00135	1.3E+04	0	0.00		0.00 - 0.02	NE-00136	9.8E+06	0	0.0		0.0 - 18.9
Location #25	10.5	NE-00131	1.3E+04	0	0.00		0.00 - 0.03	NE-00132	4.1E+06	0	0.0		0.0 - 7.9
Location #26	12.2	NE-00133	1.2E+04	1	0.01		0.00 - 0.04	NE-00134	4.5E+06	1	4.5		0.8 - 17.5
Location #27	9.7	NE-00129	2.1E+04	2	0.04		0.01 - 0.12	NE-00130	6.2E+06	0	0.0		0.0 - 11.9
Location #28	7.6	NE-00119	7.7E+03	0	0.00		0.00 - 0.01	NE-00120	4.8E+06	0	0.0		0.0 - 9.3
Location #29	6.1	NE-00117	1.1E+04	0	0.00		0.00 - 0.02	NE-00118	3.3E+06	0	0.0		0.0 - 6.2
Location #30	15.5	NE-00157	6.3E+04	0	0.00		0.00 - 0.12	NE-00158	9.7E+06	0	0.0		0.0 - 18.6
Location #31	16.0	NE-00155	6.3E+04	0	0.00		0.00 - 0.12	NE-00156	9.7E+06	1	9.7		1.7 - 38.0
Location #32	16.9	NE-00153	6.3E+04	0	0.00		0.00 - 0.12	NE-00154	9.8E+06	1	9.8		1.7 - 38.1
Location #33	16.3	NE-00149	6.3E+04	0	0.00		0.00 - 0.12	NE-00150	9.7E+06	0	0.0		0.0 - 18.6
Location #34	13.8	NE-00104	4.2E+04	1	0.04		0.01 - 0.17	NE-00105	3.4E+06	0	0.0		0.0 - 6.6
Location #35	12.7	NE-00108	5.1E+04	0	0.00		0.00 - 0.10	NE-00109	2.0E+06	0	0.0		0.0 - 3.9

TABLE 4-1
NATURE AND EXTENT OF LA IN TREE BARK AND DUFF FROM THE FOREST

Location	Approx. Distance from Mine Site (miles)	Tree Bark						Duff					
		Sample ID	Sensitivity (cm^{-2})	N Total LA Structures	Surface Loading (Ms/cm^2)		Poisson 90% CI on Surface Loading (Ms/cm^2)	Sample ID	Sensitivity (g^{-1})	N Total LA Structures	Conc. (Ms/g, dw)		Poisson 90% CI on Conc. (Ms/g)
Location #36	9.6	NE-00095	5.1E+04	0	0.00		0.00 - 0.10	NE-00096	5.8E+06	0	0.0		0.0 - 11.2
Location #37	11.1	NE-00097	2.2E+04	0	0.00		0.00 - 0.04	NE-00098	3.1E+06	0	0.0		0.0 - 5.9
Location #38	8.9	NE-00127	3.1E+04	0	0.00		0.00 - 0.06	NE-00128	2.6E+06	0	0.0		0.0 - 5.0
Location #39	7.5	NE-00125	1.2E+04	0	0.00		0.00 - 0.02	NE-00126	5.1E+06	0	0.0		0.0 - 9.8
Location #40	6.6	NE-00219	4.9E+04	17	0.8	*	0.55 - 1.22	NE-00220	1.6E+06	0	0.0	*	0.0 - 3.2
Location #41	10.3	NE-00147	9.3E+04	0	0.00		0.00 - 0.18	NE-00148	9.7E+06	0	0.0		0.0 - 18.7
Location #42	10.3	NE-00102	1.5E+04	4	0.06		0.02 - 0.12	NE-00103	2.6E+06	0	0.0		0.0 - 4.9
Location #43	12.5	NE-00106	2.1E+04	2	0.04		0.01 - 0.12	NE-00107	3.6E+06	0	0.0		0.0 - 7.0
Location #44	15.1	NE-00151	6.3E+04	0	0.00		0.00 - 0.12	NE-00152	9.1E+06	0	0.0		0.0 - 17.5
Location #45	14.3	NE-00159	6.3E+04	0	0.00		0.00 - 0.12	NE-00160	9.9E+06	0	0.0		0.0 - 19.0
Location #46	8.6	NE-00123	1.3E+04	0	0.00		0.00 - 0.02	NE-00124	3.2E+06	0	0.0		0.0 - 6.2
Location #46	8.6	*NE-00121*	*1.1E+04*	*0*	*0.00*		*0.00 - 0.02*	*NE-00122*	*3.8E+06*	*0*	*0.0*		*0.0 - 7.4*
Location #47	10.5	NE-00205	2.7E+04	0	0.00		0.00 - 0.05	NE-00206	5.7E+06	0	0.0		0.0 - 10.9
Location #48	7.6	NE-00137	3.7E+04	1	0.04		0.01 - 0.15	NE-00138	5.7E+06	1	5.7		1.0 - 22.2
Location #49	8.0	NE-00235	3.7E+04	16	0.6	*	0.38 - 0.87	NE-00236	1.5E+06	1	1.5	*	0.3 - 6.0
Location #50	6.4	NE-00203	3.4E+04	1	0.03		0.01 - 0.13	NE-00204	5.2E+06	0	0.0		0.0 - 10.1
Location #51	5.1	NE-00237	4.5E+03	1	0.004	*	0.00 - 0.02	NE-00238	9.0E+05	6	5.4	*	2.7 - 10.1

+ One or more chrysotile structures were noted in this sample.

* Sample preparation deviated from SAP/QAPP, see Laboratory Modification #LB-000092.

CI = confidence interval

cm^{-2} = per square centimeter

Conc. = concentration

g^{-1} = per gram

ID = identification

LA = Libby amphibole

Ms/cm^2 = million structures per square centimeter

Ms/g, dw = million structures per gram (dry weight)

N = number

TABLE 5-1
FIELD DUPLICATE COMPARISON

Panel A: Tree Bark

Location	Sample Type	Tree Bark					Poisson Ratio Comparison (90% confidence interval)
		Sample ID	Sensitivity (cm^{-2})	N Total LA Structures	Surface Loading (Ms/cm^2)		
Location #16	Field Sample	NE-00227	1.34E+04	6	0.08	*	[0-2.97] The rates are not different
	Field Duplicate	*NE-00242*	*6.12E+04*	*0*	*0.00*		
Location #18	Field Sample	NE-00079	2.59E+04	0	0.00		Both counts are 0; the rates are not different
	Field Duplicate	*NE-00081*	*1.14E+04*	*0*	*0.00*		
Location #46	Field Sample	NE-00123	1.26E+04	0	0.00		Both counts are 0; the rates are not different
	Field Duplicate	*NE-00121*	*1.09E+04*	*0*	*0.00*		

Panel B: Duff

Location	Sample Type	Duff					Poisson Ratio Comparison (90% confidence interval) [a]
		Sample ID	Sensitivity (g^{-1})	N Total LA Structures	Conc. (Ms/g, dw)		
Location #16	Field Sample	NE-00228	3.62E+06	7	25.4	*	[5.13-82.75] Rate 1 is greater than Rate 2
	Field Duplicate	*NE-00243*	*4.58E+05*	*3*	*1.4*		
Location #18	Field Sample	NE-00080	3.97E+05	0	0.0		Both counts are 0; the rates are not different
	Field Duplicate	*NE-00082*	*4.89E+05*	*0*	*0.0*		
Location #46	Field Sample	NE-00124	3.25E+06	0	0.0		Both counts are 0; the rates are not different
	Field Duplicate	*NE-00122*	*3.84E+06*	*0*	*0.0*		

[a] Rate 1 = field sample; Rate 2 = field duplicate

cm^{-2} = per square centimeter
Conc. = concentration
g^{-1} = per gram
ID = identification
LA = Libby amphibole
Ms/cm^2 = million structures per square centimeter
Ms/g, dw = million structures per gram (dry weight)
N = number

* Sample preparation deviated from SAP/QAPP, see Laboratory Modification #LB-000092.

TABLE 5-2
EVALUATION OF REPLICATE ANALYSES FOR TREE BARK AND DUFF

Panel A: Tree Bark

Location	Approx. Distance from Mine Site (miles)	Tree Bark														
		Sample ID		Replicate #1				Replicate #2				Replicate #3				Mean Surface Loading (Ms/cm^2)
				Sensitivity (cm^{-2})	N Total LA Structures	Surface Loading (Ms/cm^2)		Sensitivity (cm^{-2})	N Total LA Structures	Surface Loading (Ms/cm^2)		Sensitivity (cm^{-2})	N Total LA Structures	Surface Loading (Ms/cm^2)		
Location #09	5.8	NE-00223	*	14,686	2	0.03		13,360	0	0.0		13,360	0	0.0		**0.01**
Location #14	4.5	NE-00115		28,271	4	0.1		28,271	3	0.08		28,271	3	0.08		**0.09**
Location #20	7.7	NE-00087		23,189	110	2.6		23,189	113	2.6		23,189	88	2.0	a	**2.4**
Location #36	9.6	NE-00095		51,291	0	0.0		34,194	0	0.0		34,194	0	0.0		**0.00**
Location #40	6.6	NE-00219	*	48,952	17	0.8		6,680	2	0.01	b	91,849	8	0.7		**0.5**

Panel B: Duff

Location	Approx. Distance from Mine Site (miles)	Duff														
		Sample ID		Replicate #1				Replicate #2				Replicate #3				Mean Conc. (Ms/g, dw)
				Sensitivity (g^{-1})	N Total LA Structures	Conc. (Ms/g, dw)		Sensitivity (g^{-1})	N Total LA Structures	Conc. (Ms/g, dw)		Sensitivity (g^{-1})	N Total LA Structures	Conc. (Ms/g, dw)		
Location #03	11.3	NE-00212	*	3.2E+05	1	0.3		4.3E+05	1	0.4		4.7E+05	0	0.0		**0.3**
Location #06	11.8	NE-00144		9.9E+06	1	10		9.9E+06	1	10		9.9E+06	1	10		**10**
Location #12	5.1	NE-00216	*	4.8E+05	6	2.9		2.0E+06	1	2.0		2.0E+06	0	0.0		**1.6**
Location #16	5.0	NE-00228	*	3.6E+06	7	25	c	5.4E+05	1	0.5		6.1E+05	2	1.2		**9.0**
Location #25	10.5	NE-00132		4.1E+06	0	0.0		2.8E+06	0	0.0		2.8E+06	0	0.0		**0.0**

cm^{-2} = per square centimeter
Conc. = concentration
g^{-1} = per gram
ID = identification
LA = Libby amphibole
Ms/cm^2 = million structures per square centimeter
Ms/g, dw = million structures per gram (dry weight)
N = number

<u>Poisson ratio comparison test footnotes:</u>
a Replicate #3 is lower than Replicate #2
b Replicate #2 is lower than both Replicate #1 and Replicate #3
c Replicate #1 is higher than both Replicate #2 and Replicate #3

* Sample preparation deviated from SAP/QAPP, see Laboratory Modification #LB-000092.

Data Summary Report:
Nature and Extent of LA Contamination in the Forest
Libby Asbestos Superfund Site, Libby, Montana

APPENDICES

[provided electronically upon request and approval by EPA]